ARTICLE II STORM

DRAINAGE

SECTION 2.1 Standard Provisions

Standard Provisions

All construction for storm drainage in the development or improvement of property within the City of Stephenville shall conform to the following standards and requirements:

1. Storm sewer inlets shall be provided along paved streets at such intervals as are necessary to limit the depth of flow as follows:

   All Streets - Streets shall be designed to flow not more than curb deep during the 5 year storm.

   Residential Streets - Based on parkway slopes of *VA* inch per toot behind the curb, the 100 year Design Frequency flows shall not exceed a depth of 2-Y2 inches over the top of curb, and the area behind the curbs must be graded in such a manner as to contain the 100 year flow within the right-of-way.

   Collector Streets - Based on parkway slopes of *V^* inch per foot behind the curb, the 100 year Design Frequency flow shall not exceed a depth of 2Y2 inches over the top of curb. and the area behind the curb shall be graded in such a manner as to contain the 100 year flow within the right-of-way.

   Arterials - Based on a transverse slope of ¼ inch per foot on the pavement, the 100 year Design Frequency flow shall not exceed a depth of 1 inch over the lowest curb and the area behind the curb shall be graded so as to contain the 100 year flow within the street right-of-way.

   Alleys - The 100 year Design Frequency flow **shall not exceed the capacity** of the alley right-of-way.

   Positive Overflow - The approved drainage system shall provide tor positive overflow at all low points. The term "positive overflow" means that when the inlets do not function properly or when the design capacity of the conduit is exceeded, the excess flow can be conveyed over land along a concrete paved course. Normally, this would mean along a street or alley but may require the dedications of special drainage easements on private property.

2. A closed storm sewer system shall be required to accommodate runoff exceeding the street capacity, as provided above, up to and including the design capacity of a seventy-two (72) inch concrete pipe. The following are recommended maximum design velocities:

Culverts	15 fps
Inlet Laterals	10 fps
Storm Sewers	12.5 fps

Discharge velocities cannot exceed the permitted velocity of the channel or conduit at the • outfall.

3. An open channel may be permitted to accommodate runoff exceeding the design capacity of a seventy-two (72) inch pipe, as provided below:

a. Channels draining an area with a "CA" factor (coefficient of runoff and drainage area. as used hereinafter described "rational formula") of less than 250 shall be concrete lined to the design depth, plus six (6) inch freeboard except that a closed system as provided above may be used. A twenty (20) foot wide access easement shall be provided along at least one side parallel to the channel.

b. Channels draining an area with a "CA" factor of more than 250 but less than 500 shall be concrete lined to contain the runoff from a ten (10) year return frequency storm with the balance of the required design frequency storm contained within grassed slopes no steeper than three (3) horizontal to one (1) vertical and with a minimum of one foot (1') freeboard.

c. Channels draining an area with a "CA" factor of more than 500 but less than 1,000 shall be constructed with a reinforced concrete pilot channel not less than twelve feet (12') in width and having at least six inch (6") curbs, a four inch (4") depressed invert and an appropriate edge protection as accepted by the City's authorized representative. The remainder of the channel shall consist of earthen side slopes with proper vegetative cover on slopes not steeper than 3 to 1.

d. Channels draining an area with a "CA" factor over 1,000 shall be designed to carry the capacity of a 100 year flood frequency storm. The specific design and type of construction improvements for this drainage facility shall have specific approval by the City's authorized representative after review of maintenance, erosion, and site conditions.

e. All areas of an earth channel section shall be improved by the Developer with a low maintenance vegetation as approved by the City's authorized representative prior to planting. The selection of materials shall comply with the current ground cover listing for North Central Texas furnished through the Texas Agricultural Extension Service.

f. The setback for the building line shall be as follows:

1) A maintenance strip shall be provided with a twenty (20) foot width along each side of the top of the channel unless approved otherwise by the City's authorized representative and shown on the filed plat.

2) A drainage flume section, which provides for limited flow of stormwater, shall be located within a drainage easement of sufficient width to permit future maintenance accessibility.

g. A drainage feature which is to remain in its natural state of native growth may be accepted by the City to remain as an unimproved facility so long as the water conveyance capacity of the area is adequate to handle the future drainage requirements.

h. In lieu of the improvements of a channel draining an area with a "CA" factor in excess of 500, the City Council may elect to accept the dedication of all land within the 100 year floodway of the existing drainage channel as a permanent drainage right-of-way.

I. The criteria for drainage improvements as herein-above set forth in Paragraphs (a) through (e) of this section shall be applicable to publicly owned lands solely at the discretion of the City of Stephenville.

j. Easements - Drainage and floodway easements shall be provided for all open channels. Easements shall encompass all areas beneath a ground elevation defined as being the highest elevation of the following:

1) One (1) foot above a design storm having a recurrence interval of one hundred (100) years, calculated by the City's criteria.

2) The top of the high bank.

3) Maintenance access.

k. Ground Cover - Any ground cover or vegetation which is planted and is a part of the improvement project will not be accepted by the City until the growth has been established to the satisfaction of the City.

SECTION **2.2** Responsibility of Owner of Developer for Storm Drainage

1. The owner or developer of property to be developed shall be responsible for all storm drainage flowing through or abutting such property. This responsibility includes the drainage directed to that property by ultimate development as well as the drainage from ultimate development that naturally flows through the property by reason of topography. It is the intent of this Ordinance that provision be made for storm drainage in accordance with Section 2.1 at such time as any property affected is proposed for development, use or modification.

2. Where the improvement or construction of a storm drainage facility is required along a property line common to two or more owners, the owner hereafter proposing development of his property shall be responsible for the required improvements at the time of development, including the dedication of all necessary right-of-way or easements, **to** accommodate the improvements.

3. Where a property owner's proposed development uses only a portion of his property, provision for storm drainage in accordance with Section 2.1 shall only be required in that portion of the property proposed for immediate development, except as construction or improvements of a drainage facility outside that designated portion of the property is deemed essential to the development of that designated portion.

4. When a property owner proposes a development, the owner shall include provisions and plans for control of siltation and downstream erosion. If siltation or downstream erosion occurs, the owner will be responsible to remove siltation or make repairs to eroded areas at his own expense until the owner has established ground cover or vegetation to a condition of growth acceptable to the city.

5. The owner or owners shall dedicate to the City the required drainage easements. Determination of the minimum easements required shall be made by the City's authorized representative.

6. In the event that a property owner or developer desires to modify an existing pond or lake or desires to impound storm water by excavation, filling or construction of a dam within a property for retention or detention, thereby creating a lake, pond, lagoon or basin as a part of the planned development of that property, the standard provisions for storm drainage as established in Section 2.1 of this Ordinance shall be applicable and shall also provide the following:

a. An engineering plan for such construction, accompanied by complete drainage design information prepared by registered professional engineer, shall have been approved by the City of Stephenville.

b. The owner or developer shall have agreed to retain under private ownership the lake, pond, lagoon, or basin constructed, and to assume full responsibility for the protection of the general public from any health or safety hazards related to the lake, pond, or lagoon constructed.

c. The owner or developer shall have agreed to assume full responsibility **for the** maintenance of the lake, pond, lagoon, or basin constructed.

d. The obligation herein shall run with the land and shall be a continuing obligation of the owner or owners of such land.

e. All Federal, State, and County laws pertaining to impoundment of surface water are complied with including the design, construction and safety of the impounding structure. Any existing structure, which is included in a project development area. shall be improved to comply with the applicable Federal, State. County and City safety requirements for structures. The design flows shall be based upon the urbanized drainage flows which can result from a 100 year flood. All improvements shall be made to the dam structure at the expense of the developer, prior to acceptance of the adjacent street, utilities and drainage improvements as provided for under the Subdivision Ordinance.

f. On any existing structure, the owner will furnish a study by a professional engineer to the City for approval prior to any proposed alteration. Compensatory storage shall be provided in some manner such that equal or comparable flood retention capacity is maintained.

7. The maintenance of private drainage facilities shall be provided by the property owner **or** assigned agent. The City shall be kept advised of the responsible agent.

8. All existing water seepage springs or flowing water shall be connected into an underground storm sewer system where such a system is available.

9. The developer shall provide detailed off-site drainage plans for the proper transition to natural ground or stream elevations. Criteria for on-site development shall apply to off-site improvements as required by the City's authorized representative.

SECTION **2.3** Engineering Design

1. Each storm drainage facility, including street capacities, shall be designed to convey the runoff which results from a certain prescribed design storm.

Drainage design requirements for open and closed systems shall provide protection for property during a storm having a 100 year recurrence interval with this projected flow carried in the streets and closed drainage systems in accordance with the following:

Drainage Facility	Design Recurrence Interval
Closed storm sewer systems	5 yr. w/emergency 100-yr. overflow
Closed storm sewer systems at street low point or sag	25 yr. w/emergency 100-yr. overflow
Culverts and bridges	25 yr. (structure or adjacent real property must not be damaged by 100-yr. storm)
Channels - Concrete Lined (CA<250)	25 yr. w/emergency 100-yr. overflow
Concrete Lined (CA>250<500)	10 yr. w/100-yr. overflow contained within grassed slopes
Concrete Pilot Channel (CA>500<1000)	100 year
Earthen Channels (CA>1000)	100 year

2. Computation of stormwater runoff for drainage areas less than 150 acres shall be by the "Rational Method", which is based on the principle that the maximum rate of runoff from a given drainage area for an assumed rainfall intensity occurs when all parts of the area are contributing to the flow at the point of discharge. The formula for calculation of runoff by the "Rational Method" is:

Q = CIA. where

Q = The maximum rate of discharge, expressed in cubic feet per second.

I = Rainfall intensity in inches per hour from the applicable curves of Plate 1. Time of concentration or duration of rainfall for use in Plate 1 shall be calculated by velocity data shown in Table 2.1.

C = A runoff coefficient which varies with the topography, soil, soil cover, land use and moisture content of the soil at the time the runoff producing rainfall occurs. This runoff coefficient shall be based on the ultimate use of the land as recommended by the Master Plan for the City of Stephenville and shall be selected from Table 2.2 herein on the basis of the use shown on land use and zoning map of the Comprehensive Zoning Ordinance for the City of Stephenville. If an area has had a change of zoning to give the area land use for which the "C" in Table 2.2 is higher than use shown on land use and zoning maps, the higher "C" factor shall be used.

A = The drainage area, expressed in acres, contributing to the runoff at the point in question. Calculation of the drainage area shall be made from a contour map of one (1) foot intervals of which a copy shall be submitted with the engineering plans for approval. On large drainage areas or areas with steep slopes and if approved by the City's authorized representative, maps with a contour interval of greater than one *(V)* foot may be used for drainage area computations.

For drainage areas over 150 acres but less than 1000 acres, either the Rational Method or the Unit Hydrograph Flood Determination Method may be used.

For drainage areas in excess of 1000 acres, the use of a Unit Hydrograph Flow Determination shall be made. The use of a unit Hydrograph calculation will be based upon standard and accepted engineering principles normally used in the profession subject to the approval of the City's authorized representative. The Soil Conservation Service Technical Release Number 55 is an acceptable method.

Computation of runoff shall be based on a fully developed drainage area or watershed in accordance with the land use projected in the current comprehensive land use plan for the City of Stephenville. The developer and/or builder shall develop site development plans so that the rate of runoff created by the development of their property does not exceed the rate of runoff resulting from an R-1 zoning unless the Developer, through an engineering analysis, can demonstrate to the City's authorized representative that the proposed runoff has no adverse effect either on the receiving stream or downstream real property.

Table 2.1

Average Velocity for Use in Determining Time of Concentration

Description **of** Water Course	0% to 3% V. in f.p.s.	4% to 7% V. in f.p.s.	8% to 11 % V. in f.p.s.	Over 12% V. in f.p.s.
Surface drainage	5	9	13	15
Channels	Determine V. by Manning's Formula			
Storm sewers	Determine V. by Manning's Formula			

Average velocities of Table 2.1 are to be used for calculating the time of concentration or "Rainfall Duration" as set forth on Plate 1 unless the designer shows calculation of velocities for streets and/or storm sewers.

3. The Rational Method will be used for drainage areas less than 150 acres and may be used for areas between 150 and 1,000 acres. As the Rational Method is used and detention is required, the volume of water supplied by the design storm may be calculated by converting the runoff rate, during a specific duration, to volume. The inflow volume should be determined for a period of at least twice the time of concentration for the site.

Table 2.2 Values of "C" for Use in "Rational Method" Formula Q = CIA

Slope	Land Use From Master Plan	Value of "C" (Runoff Coefficient-Rational Method)
Flat 0% to 1%	Park areas. No developable land	**0.20**
	Park and school land tract	**0.30**
	Single family residential	**0.45**
	Duplex	**0.50**
	Multiple family	**0.55**
	Local business	**0.65**
	Central business	**0.80**
	Commercial	**0.80**
	Industrial	**0.75**
Moderate 1% to 3 ½%	Park areas - No developable land	**0.30**
	Park and school land tract	**0.40**
	Single family residential	**0.50**
	Duplex	**0.55**
	Multiple family	**0.60**
	Local business	**0.70**
	Central business	**0.85**
	Commercial	**0.85**
	Industrial	**0.80**
Steep 3.5% and over	Park areas - No developable land	**0.35**
	Park and school land tract	**0.45**
	Single family residential	**0.65**
	Duplex	**0.70**
	Multiple family	**0.75**
	Local business	**0.80**
	Central business	**0.85**
	Commercial	**0.85**
	Industrial	**0.85**

Retention and detention are two generalized types of storm runoff storage used to control the rate of runoff. All detention ponds should be designed to empty within a 24 hour period.

Using the average velocities from this table, the designer shall calculate the time of concentration by the following formula unless more data is shown on the plans for calculating time of concentration.

"Inlet Time" = 5 minutes for property zoned for multiple family, local business, central business, commercial or industrial; 10 minutes for property zoned for parks, schools, single family residential and duplex.

$$T = \text{"Inlet Time"} + \frac{D}{V \times 60}$$ Where:

T = Time of concentration in minutes for use in Plate 3.

D = Distance in feet from point of concentration to upper end of drainage area under consideration.

V = Velocity in feet per second from this table or velocity calculated by designer for streets and/or storm sewers.

The existing soils are such that erosive conditions are created at certain velocities. The following velocities are considered to be maximum acceptable design conditions:

Earth (with no concrete protection)	0 to 5 feet per second
Shale	6 to 10 feet per second
Rock	10 feet per second

4. The minimum curb inlet size shall be eight (8) feet in length with a minimum capacity of 8 cfs.

5. The construction of all improvements shall be in accordance with the standards set forth in the City's rainfall intensity chart in years (Plate 1). the Inlet Capacity for Low Point Inlets (Plate 2), the Drainage Capacity for Road Sections (Plate 3), and the Typical Sections of Drainage Channels (Plate 4) are hereby adopted as a part of this Ordinance.

6. Complete engineering plans for storm drainage facilities shall be prepared by a professional engineer, registered in the State of Texas, and experienced in civil engineering work. The total cost for such engineering plans and specifications shall be borne by the owner or the developer and shall be furnished to the City's authorized representative for review and approval.

7. In any development, alternation or improvement of property, the owner may be required to provide at his expense a preliminary drainage study for the total area to be ultimately developed. This study shall be submitted to the City's authorized representative as a part of the submitted data for consideration of Preliminary Plat or Site Plan approval.

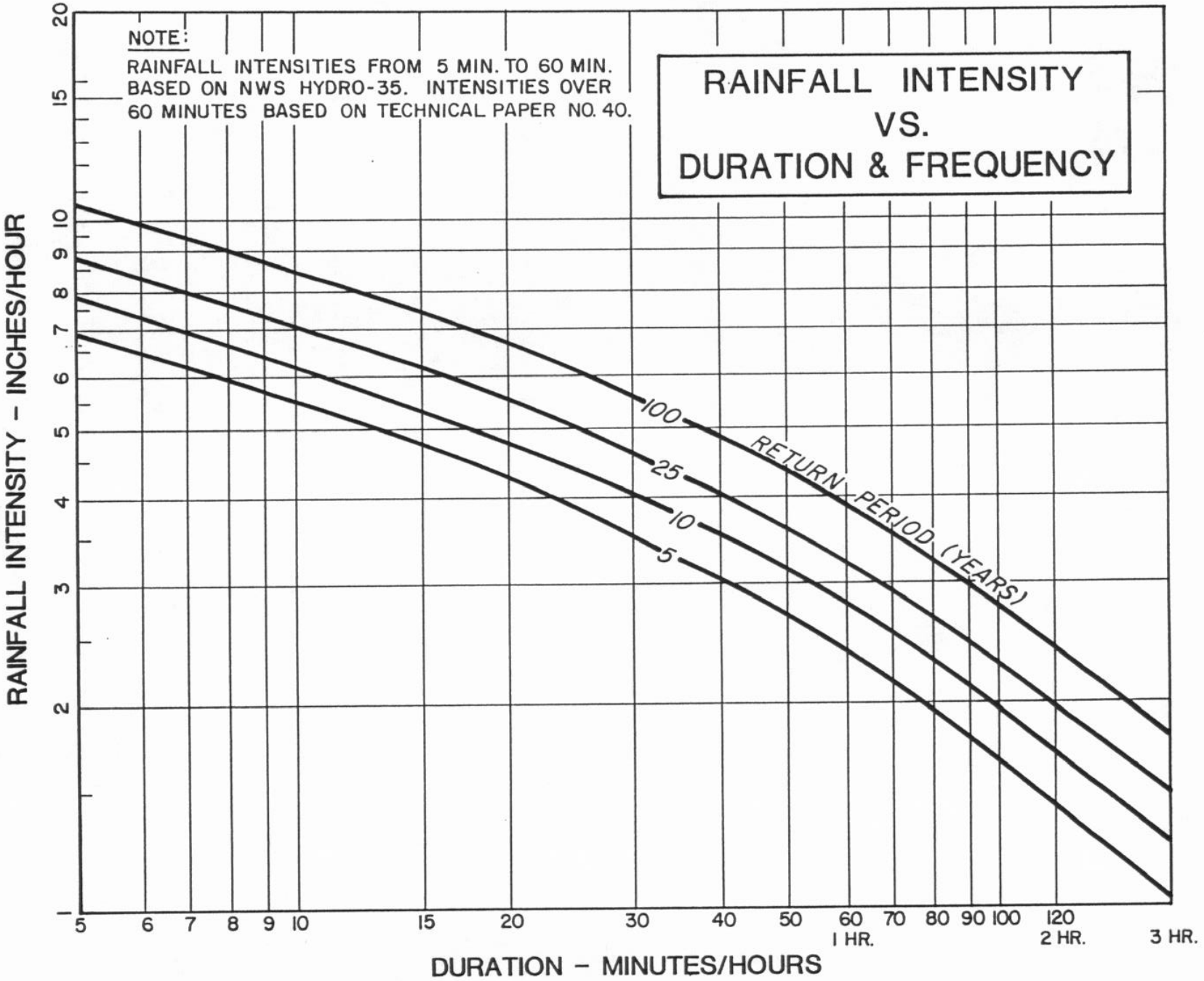
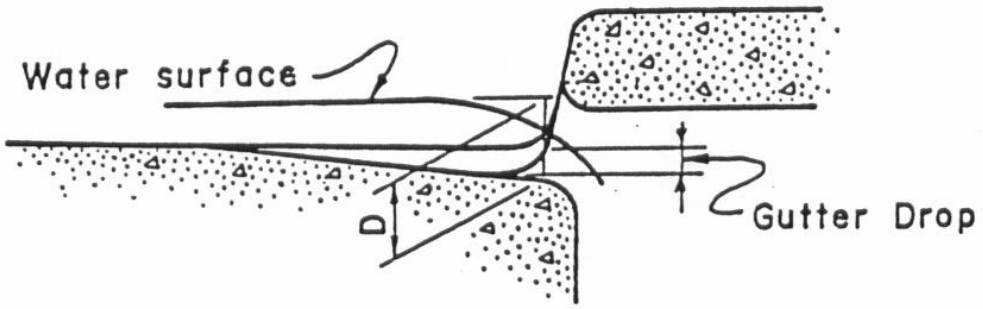
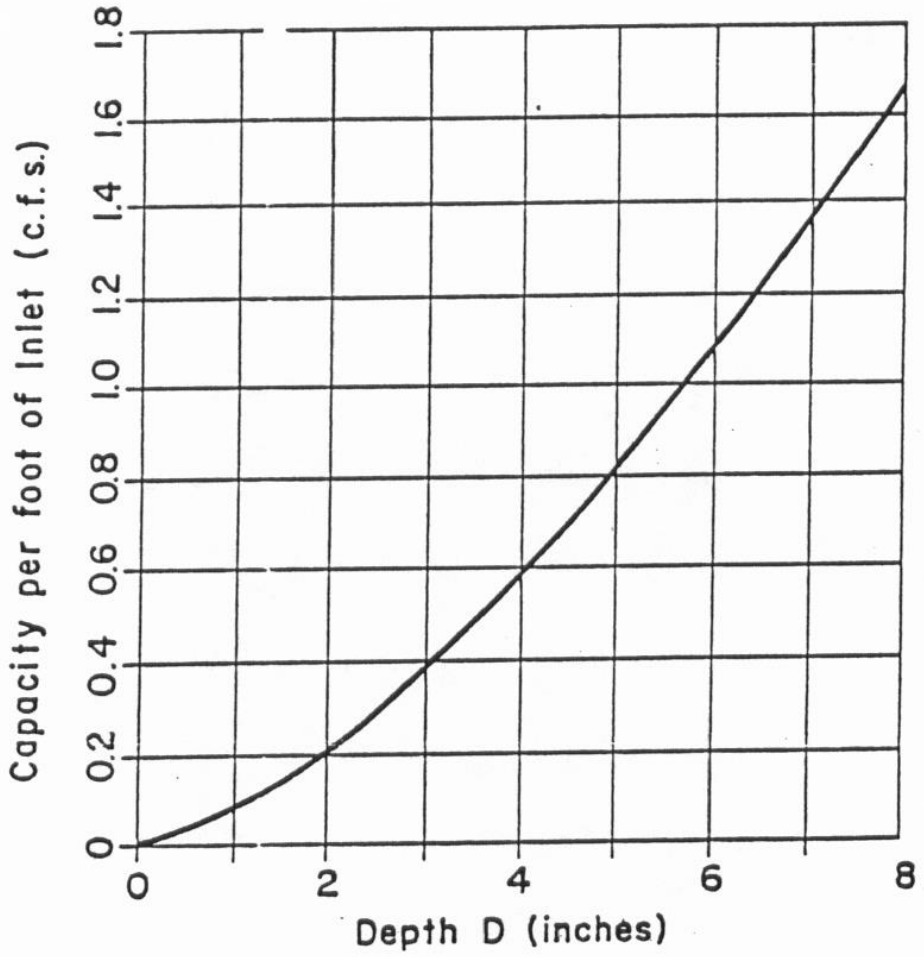

NOTE:
RAINFALL INTENSITIES FROM 5 MIN. TO 60 MIN. BASED ON NWS HYDRO-35. INTENSITIES OVER 60 MINUTES BASED ON TECHNICAL PAPER NO. 40.
RAINFALL INTENSITY VS. DURATION & FREQUENCY
RAINFALL INTENSITY - INCHES/HOUR
20
15
10
9
8
7
6
5
4
3
2
1
100
25
10
5
RETURN PERIOD (YEARS)
5
6
7
8
9
10
15
20
30
40
50
60
70
80
90
100
120
1 HR.
2 HR.
3 HR.
DURATION - MINUTES/HOURS

PLATE 1

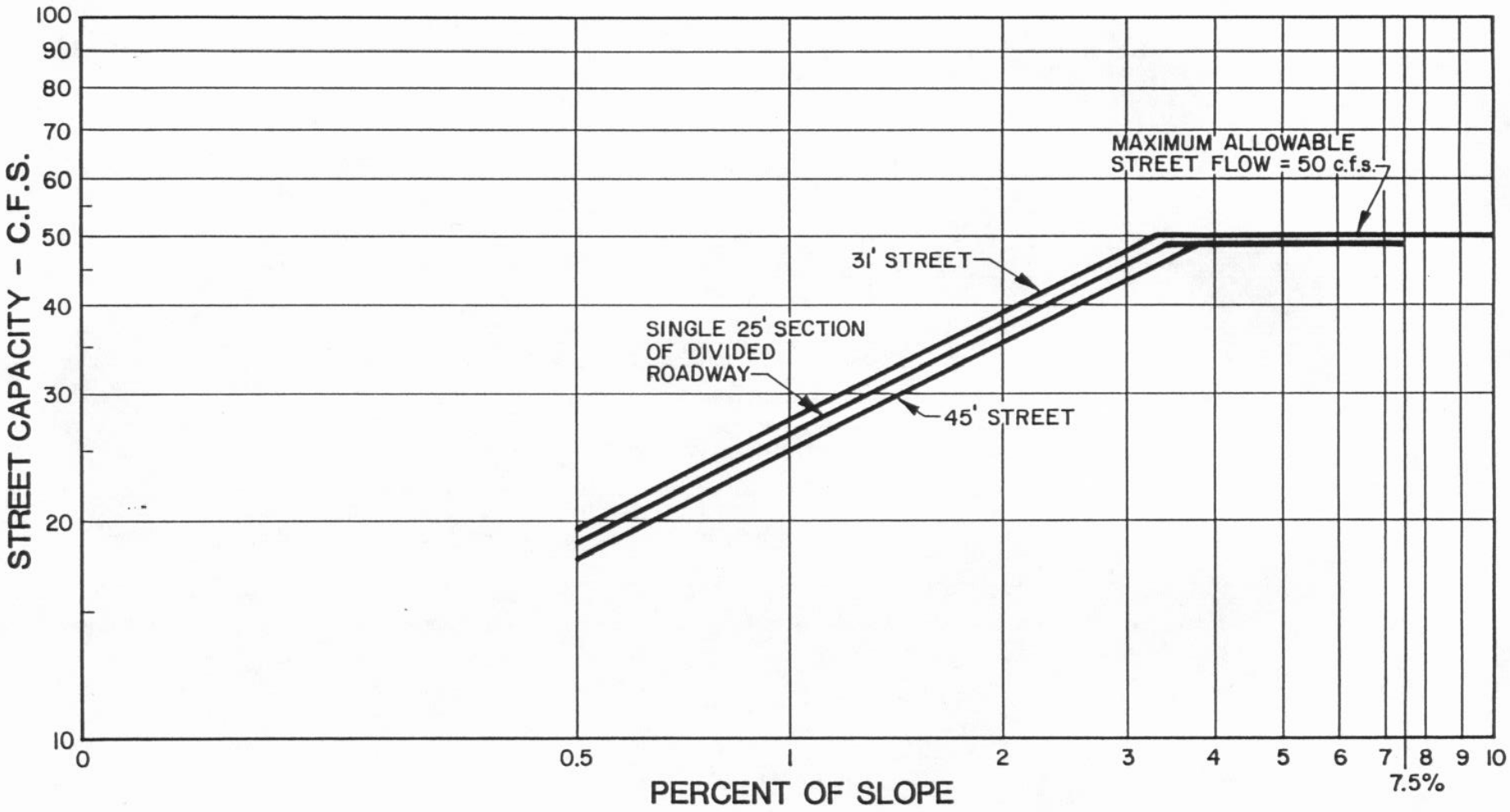


SECTION



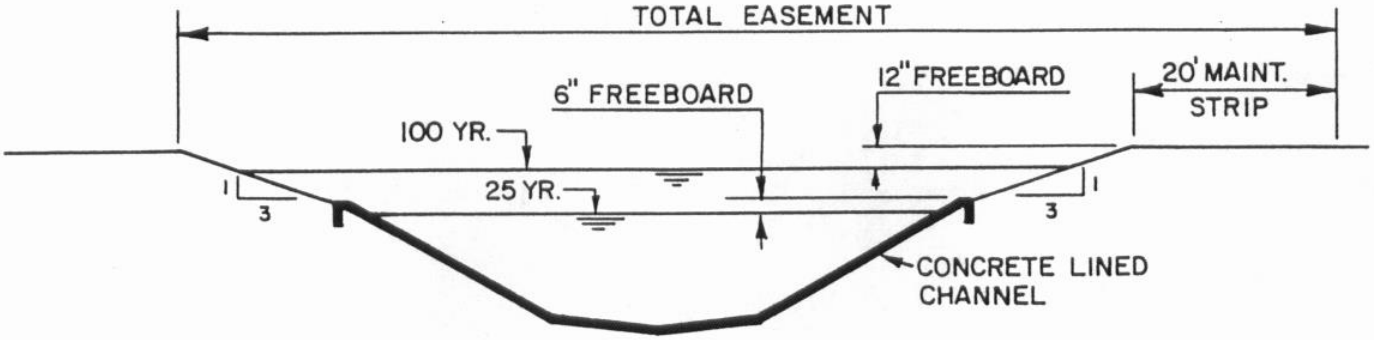
INLET CAPACITY FOR LOW POINT INLETS

PLATE 2

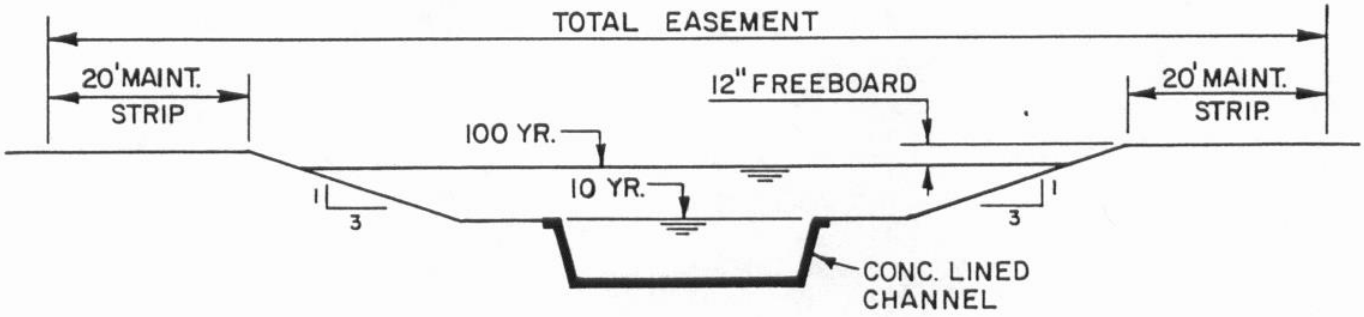


CAPACITY OF ROADWAY SECTIONS

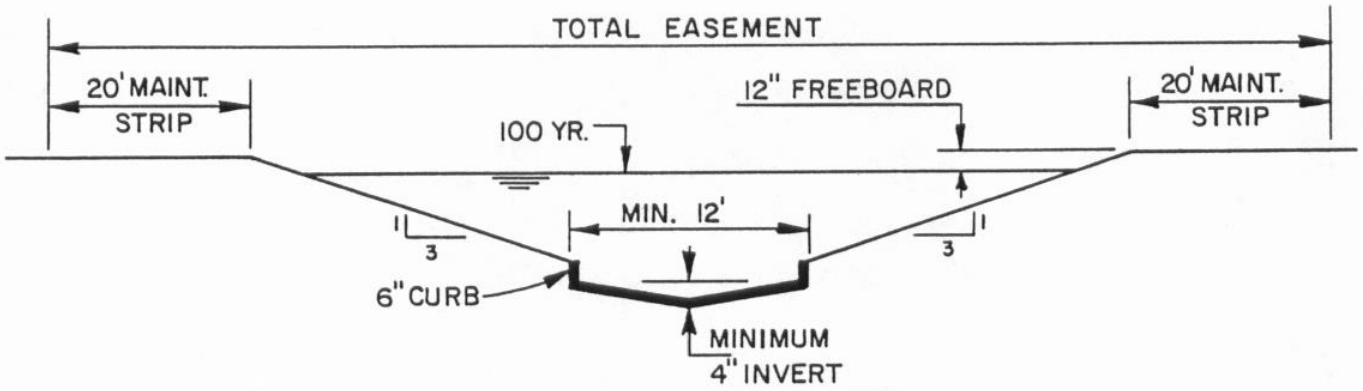
PLATE 3



CA LESS THAN 250



CA BETWEEN 250 & 500



CA BETWEEN 500 & 1000

NOTE:

CHANNELS DRAINING AREAS EXCEEDING CA FACTOR OF 1,000 SHALL BE DESIGNED TO CARRY THE CAPACITY OF A 100 YEAR FREQUENCY STORM, THE SPECIFIC DESIGN AND TYPE OF CONSTRUCTION IMPROVEMENTS SHALL HAVE SPECIFIC APPROVAL BY THE DIRECTOR OF PUBLIC WORKS OR HIS AUTHORIZED REPRESENTATIVE.

TYPICAL DRAINAGE CHANNEL SECTIONS

PLATE 4

ARTICLE II

STORM DRAINAGE

(From Ordinance No. 1987-17; August 4, 1987; Sections III through VIII)

SECTION 2.1 Standard Provisions Standard

Provisions

All construction for storm drainage in the development or improvement of property within the City of Stephenville shall conform to the following standards and requirements:

1. Storm sewer inlets shall be provided along paved streets at such intervals as are necessary to limit the depth of flow as follows:

   Residential Streets - Based on parkway slopes of 1/4 inch per foot behind the curb, the 100 year Design Frequency flows shall not exceed a depth of 1-1/2 inches over the top of curb.

   Collector Streets - Based on parkway slopes of 1/4 inch per foot behind the curb, the 100 year Design Frequency flow shall not exceed the elevation of the lowest top of curb.

   Arterials - Based on a transverse slope of 1/4 inch per foot on the pavement, the 100 year Design Frequency flow shall not exceed the elevation of the lowest top of curb.

   Alleys - The 100 year Design Frequency flows shall not exceed the capacity of the alley sections.

   Positive Overflow - The approved drainage system shall provide for positive overflow at all low points. The term "positive overflow" means that when the inlets do not function properly or when the design capacity of the conduit is exceeded, the excess flow can be conveyed over land along a concrete paved course. Normally, this would mean along a street or alley, but can require the dedications of special drainage easements on private property.

2. A closed storm sewer system shall be required to accommodate a runoff exceeding the street capacity, as provided above, up

to and including the design capacity of a seventy-two (72) inch concrete pipe. The following are recommended maximum design velocities:

Culverts	15 fps
Inlet Laterals	10 fps
Storm Sewers	12.5 fps

Discharge velocities cannot exceed the permitted velocity of the channel or conduit at the outfall.

An open channel may be permitted to accommodate runoff exceeding the design capacity of a seventy-two (72) inch pipe, as provided below;

a. Channels draining an area with a "CA" factor (coefficient of runoff and drainage area, as used hereinafter described "rational formula") of less than 600 shall be concrete lined to the design depth, plus six (6) inch freeboard except that a closed system as provided above may be used. A twenty (20) foot wide access easement shall be provided along at least one side parallel to the channel. The top width of the channel at the design depth must not exceed fifty (50) feet unless specifically approved by the City Administrative Officer or his authorized representative.

b. Channels draining an area with a "CA" factor between 600 and 1,000 shall be improved to a capacity of the 100 year design discharge by excavation, straightening, and realignment, as required, and also the construction of a concrete lined channel having a width of not less than the bottom width with concrete lines to a depth of at least three (3) feet on the banks. Earthen side slopes shall be no steeper than 4:1, horizontal to vertical, and shall have approved ground cover to prevent erosion.

c. Channels draining an area with a "CA" factor over 1,000 shall be designed to carry the capacity of a 100 year flood frequency storm. The specific design and type of construction improvements for this drainage facility shall have specific approval by the City Administrative Officer or authorized representative after review of maintenance, erosion, and site conditions.

d. All areas of an earth Channel Section shall be improved by the Developer with a low maintenance vegetation as approved by the City Administrative Officer or authorized representative prior to planting. The selection of

materials shall comply with the current ground cover listing for North Central Texas furnished through the Texas Agricultural Extension Service.

e. The setback for the building line shall be as follows:

1) A maintenance strip shall be provided with a twenty (20) foot width along each side of the top of the channel unless approved otherwise by the Director of Public Works or authorized representative and shown on the filed plat.

2) A drainage flume section, which provides for limited flow of stormwater, shall be located within a drainage easement of sufficient width which permits future maintenance accessibility.

f. A drainage feature which is to remain in its natural state of native growth may be accepted by the City to remain as an unimproved facility so long as the water conveyance capacity of the area is adequate to handle the future drainage requirements.

g. In lieu of the improvements of a channel draining an area with a "CA" factor in excess of 600, the City Council may elect to accept the dedication of all land within the 100 year floodway of the existing drainage channel as a permanent drainage right-of-way.

h. The criteria for drainage improvements as herein-above set forth in Paragraphs (a) through (d) of this section shall be applicable to publicly owned lands solely at the discretion of the City of Stephenville.

i. Excavation, fill and grading operations within the City limits and the extraterritorial jurisdiction as defined in Article 970a, Vernon's Texas Civil Statutes, shall be undertaken only after a proper permit has been obtained from the City Building Inspector. Failure to obtain the proper permit shall result in the requirement for the developer to replace the soils, as required by Chapter 70 of the Appendix of the Uniform Building Code as adopted by the City.

j. Easements - Drainage and floodway easements shall be provided for all open channels. Easements shall encompass all areas beneath a ground elevation defined as being the highest elevation of the following:

1) One (1) foot above a design storm having a recurrence interval of one hundred (100) years, calculated by the City's criteria.

2) The top of the high bank.

3) Maintenance access.

k. Ground Cover - Any ground cover or vegetation which is planted and is a part of the improvement project will not be accepted by the City until the growth has been established and maintained by the developer for a one (1) year time period.

SECTION 2.2 Responsibility of Owner or Developer for Storm Drainage

1. The owner or developer of property to be developed shall be responsible for all storm drainage flowing through or abutting such property. This responsibility includes the drainage directed to that property by ultimate development as well as the drainage from ultimate development that naturally flows through the property by reason of topography. It is the intent of this Ordinance that provision be made for storm drainage in accordance with Section 2.1 above, at such time as any property affected is proposed for development, use or modification.

2. Where the improvement or construction of a storm drainage facility is required along a property line common to two or more owners, the owner hereafter proposing development of his property shall be responsible for the required improvements at the time of development, including the dedication of all necessary right-of-way or easements, to accommodate the improvements.

3. Where a property owner's proposed development or use of only a portion of his property, provision for storm drainage in accordance with Section 2.1 above shall only be required in that portion of the property proposed for immediate development, except as construction or improvements of a drainage facility outside that designated portion of the property is deemed essential to the development of that designated portion.

4. When a property owner proposes a development, the owner shall include provisions and plans for control of siltation and downstream erosion. If siltation or downstream erosion occurs, the owner will be responsible to remove siltation or make repairs to eroded areas at his own expense until the

owner has established and maintained a ground cover or vegetation in the improvement project for a period of one (1) year.

5. The owner or owners shall dedicate to the City, the required drainage easements. Determination of the minimum easements required shall be made by the City Administrative Officer or authorized representative.

6. In the event that a property owner or developer desires to modify an existing pond or lake or desires to impound storm water by excavation, filling or construction of a dam within a property for retention or detention, thereby creating a lake, pond, lagoon or basin as a part of the planned development of that property, the standard provisions for storm drainage as established in Section 2.1 of this Ordinance shall be applicable and shall also provide the following:

   a. An engineering plan for such construction, accompanied by complete drainage design information prepared by a registered professional engineer, shall have been approved by the City of Stephenville.

   b. The owner or developer shall have agreed to retain under private ownership the lake, pond, or lagoon or basin constructed, and to assume full responsibility for the protection of the general public from any health or safety hazards related to the lake, pond, or lagoon constructed.

   c. The owner or developer shall have agreed to assume full responsibility for the maintenance of the lake, pond, or lagoon or basin constructed.

   d. The obligations herein shall run with the land and shall be a continuing obligation of the owner or owners of such land.

   e. All Federal, State, and County laws pertaining to impoundment of surface water are complied with including the design construction and safety of the impounding structure. Any Existing Struction, which is included in a project development area, shall be improved to comply with the applicable Federal, State, County and City safety requirements for structures. The design flows shall be based upon the urbanized drainage flows which can result from a 100 year flood. All improvements shall be made to the dam structure at the expense of the developer, prior to acceptance of the adjacent street,

utilities and drainage improvements as provided for under the Subdivision Ordinance.

f. On any existing structure, the owner will furnish a study by a professional engineer to the City for approval prior to any proposed alternation. Compensatory storage shall be provided in some manner such that equal or comparable flood retention capacity is maintained.

7. The maintenance of private drainage facilities shall be provided by the property owner or assigned agent. The City shall be kept advised of the responsible agent.

8. All existing water seepage springs, or flowing water shall be connected into an underground storm sewer system, or they shall be discharged into an appropriate facility which is intended to carry stormwater runoff. Such flow will not be permitted to discharge directly into the street structure.

9. The developer shall provide detailed off-site drainage plans for the proper transition to natural ground or stream elevations. Criteria for on-site development shall apply to off-site improvements as required by the City Administrative Officer or authorized representative. '

SECTION *2.3* Engineering Design

1. Each storm drainage facility, including street capacities, shall be designed to convey the runoff which results from a certain prescribed design storm.

Drainage design requirements for open and closed systems shall provide protection for property during a storm having a 100 year recurrence interval with this projected flow carried in the streets and closed drainage systems in accordance with the following:

Drainage Facility	Design Recurrence Interval
Closed storm sewer systems	10 yr. w/emergency 100 yr. overflow

Drainage Facility	Design Recurrence Interval
Closed storm sewer systems at street low point or sag	25 yr. w/emergency 100 yr. overflow

Culverts and bridges	100 yr. (unless otherwise directed)
Concrete lined channels	50 yr. w/emergency 100 yr. overflow
Earthen channels	100 yr.

2. Computation of stormwater runoff for drainage areas less than 150 acres shall be by the "Rational Method", which is based on the principle that the maximum rate of runoff from a given drainage area for an assumed rainfall intensity occurs when all parts of the area are contributing to the flow at the point of discharge. The formula for calculation of runoff by the "Rational Method" is:

Q = CIA, Where

Q = The maximum rate of discharge, expressed in cubic feet per second.

I = Rainfall intensity in inches per hour from the applicable curves of Plate 1. Time of concentration or duration of rainfall for use in Plate 1 shall be Calculated by velocity data shown in Table 2.1.

C = A runoff coefficient which varies with the topography, soil, soil cover, land use and moisture content of the soil at the time the runoff producing rainfall occurs. This runoff coefficient shall be based on the ultimate use of the land as recommended by the Master Plan for the City of Stephenville and shall be selected from Table 2.2 herein on the basis of the use shown on land use and zoning map of the Comprehensive Zoning Ordinance for the City of Stephenville. If an area has had a change of zoning to give the area land use for which the "C" in Table 2.2 is higher than use shown on land use and zoning maps, the higher "C" factor shall be used.

A = The drainage area, expressed in acres, contributing to the runoff at the point in question. Calculation of the drainage area shall be made from a contour map of one (1) foot intervals of which a copy shall be submitted with the engineering plans for approval.

For drainage areas in excess of 150 acres, the use of a Unit Hydrograph Flow Determination shall be made. The use of a unit Hydrograph calculation will be based

upon standard and accepted Engineering Principles normally used in the profession subject to the approval of the City Administrative Officer or authorized representative. The Soil Conservation Service Technical Release Number 55 is an acceptable method.

Computation of runoff shall be based on a fully developed drainage area, or watershed, in accordance with the land use projected in the current comprehensive land use plan for the City of Stephenville. The developer or builder shall develop their site development plans so that the rate of runoff created by the development of their property does not exceed the rate of runoff resulting from an R-l zoning.

Table 2.1

Average Velocity for Use in Determining Time of Concentration

Description of Water Course	0% to 3% V. in f.p.s.	4% to 7% V. in f.p.s.	8% to 11% V. in f.p.s.	Over 12% V. in f.p.s.
Surface drainage	5	9	13	15
Channels	Determine V. by Mannings Formula			
Storm Sewer	Determine V. by Mannings Formula			

Average velocities of Table 2.1 are to be used for calculating the time of concentration or "Rainfall Duratin" as called on Plate 1 unless the designer shows calculation of velocities by streets and/or storm sewers.

3. The Rational Method will be used for drainage areas less than or equal to 150 acres. As the Rational Method is used and detention is required, the volume of water supplied by the design storm may be calculated by converting the runoff rate, during a specific duration, to volume. The inflow volume should be determined for a period of at least twice the time of concentration for the site.

Table *2.2*

Values of "C" for Use in "Rational Method" Formula Q = CIA

Slope	Land Use From Master Plan	Value of "C" (Runoff Coefficient-Rational Method)
Flat 0% to 1%	Park areas, No developable land	0.20
	Park and school land tract	0.30
	Single family residential	0.45
	Duplex	0.50
	Multiple family	0.55
	Local business	0.65
	Central business	0.80
	Commercial	0.80
	Industrial	0.75
Moderate 1% to 3-1/2%	Park areas - No developable land	0.30
	Park and school land tract	0.40
	Single family residential	0.50
	Duplex	0.55
	Multiple family	0.60
	Local business	0.70
	Central business	0.85
	Commercial	0.85
	Industrial	0.80
Steep 3.5% and over	Park areas - No developable land	0.35
	Park and school land tract	0.45
	Single family residential	0.65
	Duplex	0.70
	Multiple	0.75
	Local business	0.80
	Central business	0.85
	Commercial	0.85
	Industrial	0.85

Retention and detention are two generalized types of storm runoff storage used to control the rate of runoff. All detention ponds should be designed to empty within a 24 hour period.

Using the average velocities from this table, the designer shall calculate the time of concentration by the following formula unless more data is shown on the plans for calculating time of concentration.

"Inlet Time" = the time for inlet at the upper end of the line plus the time of flow through the storm pipe from the upper end of the storm pipe to the point in question. Each component of the time of concentration can be estimated by the equation:

$$tc = \frac{DL}{(V \times 60)}$$

tc= Time of concentration (in minutes)

DL = Distance in feet from point of concentration to upper end of drainage area under consideration.

V = Velocity from Table II or calculated (in seconds per feet)

A five (5) minute minimum time of concentration shall be used for property zoned multiple family, local business, central business, commercial, or industrial; and a ten (10) minute minimum for property zoned for park areas, schools, single family, and duplex.

The existing soils are such that erosive conditions are created at certain velocities. The following velocities are considered to be maximum acceptable design conditions:

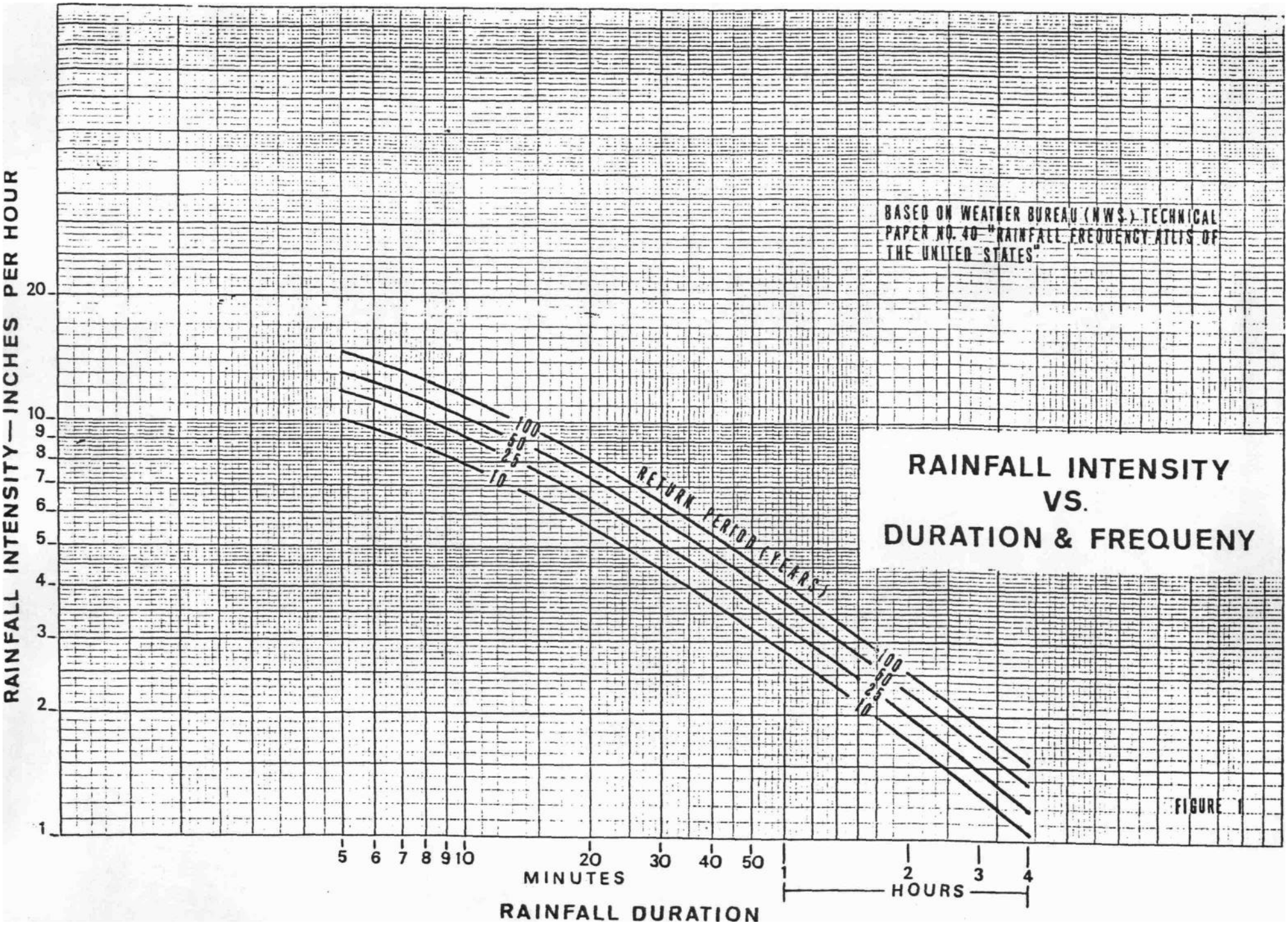
Earth (with no concrete protection)	0 to 5 feet per second
Shale	5 to 6 feet per second
Rock	6 to 10 feet per second

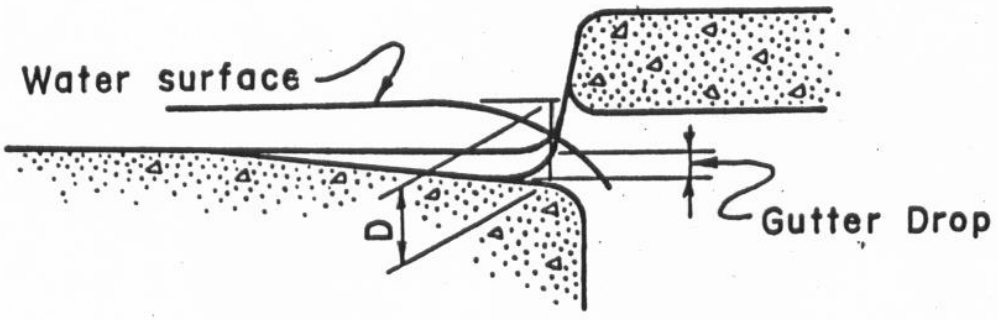
4. The minimum curb inlet size shall be eight (8) feet in length with a minimum capacity of 8 cfs.

5. The construction of all improvements shall be in accordance with the standards set forth in the City's rainfall intensity chart in years (Plate 1), the inlet Capacity for low point inlets (Plate 2), the drainage capacity road sections (Plate 3), and the Typical Sections of Drainage Channels (Plate 4), are hereby adopted as a part of this Ordinance.

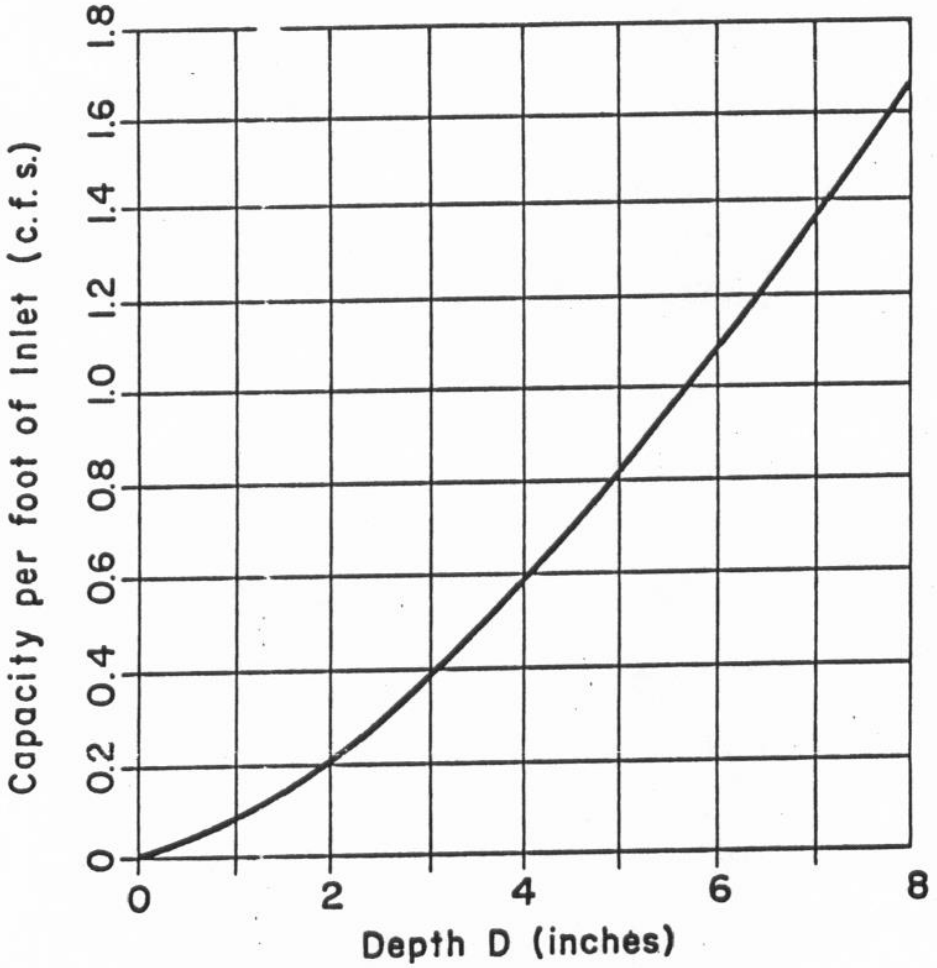
6. Complete engineering plans for storm drainage facilities shall be prepared by a professional engineer, registered in the State of Texas, and experienced in civil engineering work. The total cost for such engineering plans and specifications shall be borne by the owner or the developer and shall be furnished to the City Administrative Officer or authorized representative for his review and approval.

7. In any development, alternation or improvement of property, the owner may be required to provide at his expense a preliminary drainage study for the total area to be ultimately developed. This study shall be submitted to the City Administrative Officer or authorized representative as a part of the submitted data for consideration of Preliminary Plat or Site Plan approval.


BASED ON WEATHER BUREAU (NWS) TECHNICAL PAPER NO. 40 "RAINFALL FREQUENCY ATLAS OF THE UNITED STATES"
RAINFALL INTENSITY VS. DURATION & FREQUENY
RAINFALL INTENSITY—INCHES PER HOUR
20
10
9
8
7
6
5
4
3
2
1
100
50
25
10
RETURN PERIOD (YEARS)
100
50
25
10
5 6 7 8 9 10 20 30 40 50 1 2 3 4
MINUTES
HOURS
RAINFALL DURATION
FIGURE 1

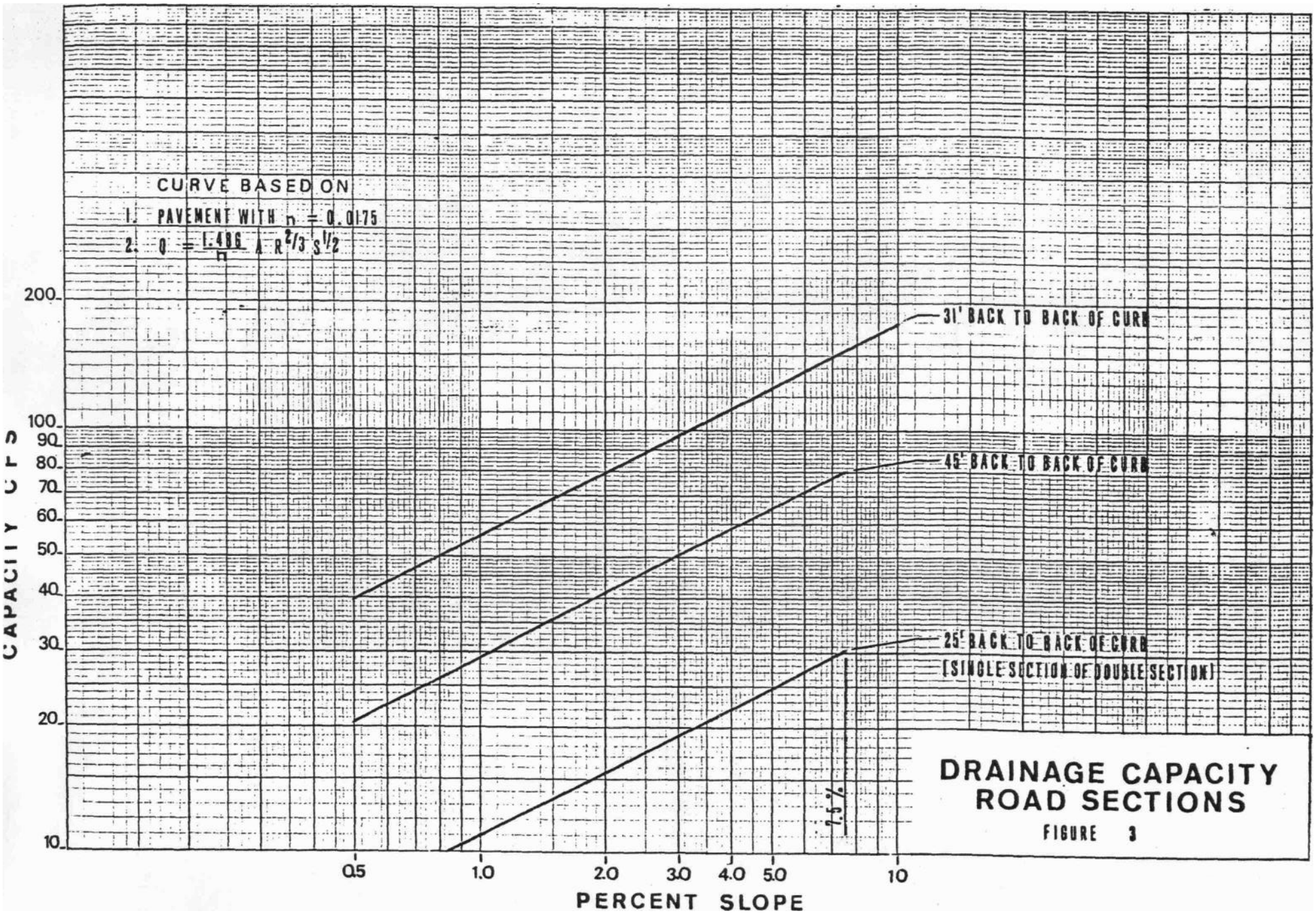


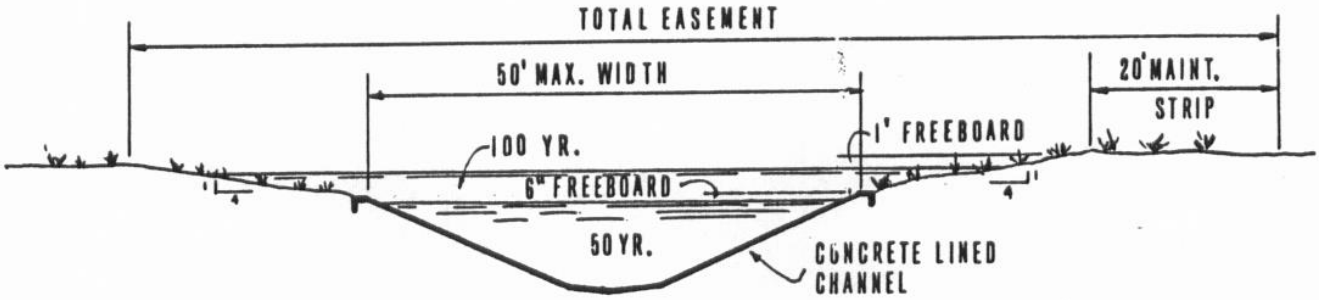
SECTION



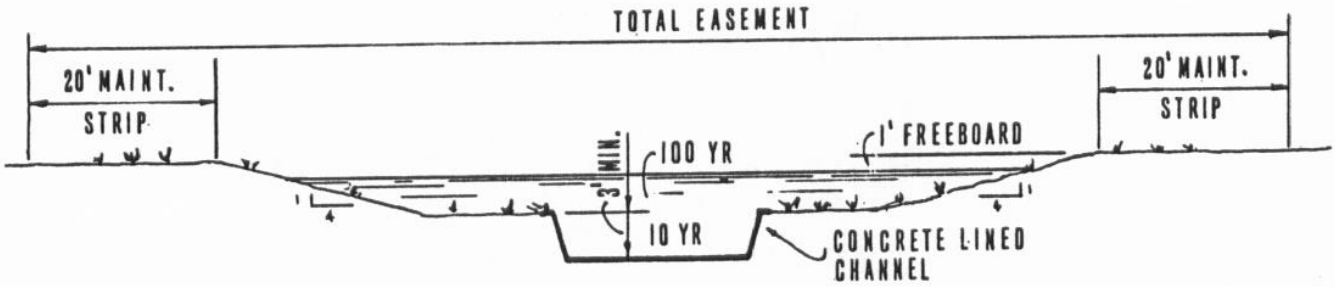
INLET CAPACITY FOR LOW POINT INLETS

FIGURE 2


CURVE BASED ON
1. PAVEMENT WITH n = 0.0175
2. Q = 1.486/n A R^2/3 S^1/2
CAPACITY CFS
200
100
90
80
70
60
50
40
30
20
10
31' BACK TO BACK OF CURB
45' BACK TO BACK OF CURB
25' BACK TO BACK OF CURB
(SINGLE SECTION OF DOUBLE SECTION)
2.5%
0.5
1.0
2.0
3.0
4.0
5.0
10
PERCENT SLOPE
DRAINAGE CAPACITY
ROAD SECTIONS
FIGURE 3



CA LESS THAN 600



CA BETWEEN 600 & 1,000

NOTE:

CHANNELS DRAINING AREAS EXCEEDING CA FACTOR OF 1,000 SHALL BE DESIGNED TO CARRY THE CAPACITY OF A 100 YEAR FREQUENCY STORM, THE SPECIFIC DESIGN AND TYPE OF CONSTRUCTION IMPROVEMENTS SHALL HAVE SPECIFIC APPROVAL BY THE DIRECTOR OF PUBLIC WORKS OR HIS AUTHORIZED REPRESENTATIVE

TYPICAL DRAINAGE CHANNEL SECTIONS

FIGURE 4

ARTICLE IIA
City Of Stephenville
DESIGN GUIDELINES
FOR
SIZING SMALL DETENTION PONDS

ARTICLE II A

DESIGN GUIDELINES FOR SIZING

SMALL DETENTION PONDS FOR CITY OF STEPHENVILLE DRAINAGE ORDINANCE

(Furnished by the City of Stephenville)

SECTION 2A.1 General

Design Standards

1. The purpose of this section is to establish minimum standard criteria, principles, procedures and practices for design of drainage improvements and small detention ponds and is not to replace the independent judgment and responsibility of the design engineer.

2. The design factors, formulas, graphs and procedures presented or referred to herein are intended for use as minimum engineering guides in the design or drainage improvements and small detention ponds.

3. Methods of design other than those indicated or referred to herein may be considered in complex and difficult cases where experience clearly indicates they are preferable; however, these deviations shall not be attempted until approval has been obtained from the City Administrative Officer or his authorized designee. If existing conditions are determined that require greater than the minimum design, it is the responsibility of the design engineer to design accordingly.

4. The methods outlined or referred to herein include accepted principles of drainage design and should be a working supplement to basic design information obtainable from text books and publications on hydrology and hydraulics.

SECTION 2A.2 Minimum Tract Size

Tracts of land of 0.5 acres or less may not require detention or controlled runoff. This would be applicable to existing developed areas not experiencing land use changes. Transitional areas where land use is being converted from single-family residential to higher densities, will require the entire area to be considered instead of the individual tracts.

SECTION 2A.3 Drainage Plan

A drainage plan should be presented on drawings accurately and

clearly representing existing and proposed improvements. All areas contributing to the runoff of the site of the proposed improvements shall be shown with contours and/or elevations. Drainage areas shall be numbered and identified in accordance to the areas as identified in the engineering drainage calculations. Computations shown on the drawings shall be submitted to the City supporting the drainage design and shall be in a form as to allow an expedient and consistent review. The sizes, flows, elevations, capacities and percentage of slope of all drainage improvements shall be shown. Drawings with computations shall be submitted in conformance to the Subdivision Ordinance and sealed by a Registered Professional Engineer in the State of Texas.

SECTION 2A.4 Street Drainage

Street flows shall not exceed a depth which is defined by the Drainage Ordinance. Streets shall be designed in accordance to the City's street standards and shall conform to the following:

1. No flattening of the standard street cross slopes shall be allowed for the purposes of obtaining additional hydraulic capacity.

2. Where additional hydraulic capacity is required on the street, the gradient must be increased or curb inlets and storm drains installed to remove a portion of the flow.

3. For noncurbed streets, all flows shall be contained within paralleling roadside ditches.

SECTION 2A.5 Small Urban Area On-Site Detention Ponds

On-site detention facilities have a single purpose of controlling the excess runoff from a particular site or subdivision. A detention facility's use is particularly beneficial in situations where a site's stormwater runoff discharges into a system with limited flow capacity. There are, however, certain minimum standards that must be adhered to within any design. The following is a listing of general as well as some specific design criteria for on-site detention ponds.

1. General Criteria for On-Site Detention

    a. The rate of outflow from the on-site detention facility shall be based on R-l (Single-Family) developed peak flow. The 100 year return frequency storm is to be used to determine the volume of detention storage required. In addition, the outlet structure shall be designed such that peak discharges are not increased for storm frequencies from the 5-year up to the 100-year frequency storm.

b. The rate of inflow to the detention facility must be calculated based on the assumption of full development of the site.

c. The outlet structures shall be designed on the basis of inlet or outlet control, which ever is applicable. The structures shall be capable of safely and properly passing the runoff flow for the entire drainage area both on and off site for the 100 year return frequency storm. The outflow structure shall discharge flows at a nonerosive rate.

d. No outlet structures from detention, filtration and/or sedimentation ponds, parking detention or other concentrating structures shall be designed to discharge concentrated flow directly onto arterial or collector streets. Such discharges shall be conveyed by a closed conduit to the nearest existing storm sewer. If there is no existing storm sewer within 300 feet, the outlet design shall revert the discharge back to sheet flow, following as nearly as possible the direction of the gutter. Any variances from this design will require approval by the City Administrative Officer.

e. Storm runoff can be detained within parking lots; however, the engineer should be aware of the inconvenience to both pedestrians and traffic. The location of ponding areas in a parking lot should be planned so that this condition is minimized. Stormwater ponding depths in parking lots are limited to an average of eight (8) inches with a maximum of 12 inches for the 100 year return frequency storm.

f. When a site is situated such that off-site flows will be draining through the property and into the pond, provisions must be made in the overflow system for these flows. The engineer should understand that by mixing of on-site with off-site flows tends to produce inefficiencies in the pond. This criteria should not be confused with in-channel detention which is discussed in g. below.

g. A detention pond that is placed within an existing channel that is accessed by more than one development shall be referred to as an in-channel detention pond. In this situation the engineer is required to perform a multihydrograph analysis which details the relationship of the existing site, the developed site with detention, and the channel. There shall be no increase at any point in the rising limb of the hydrographs when comparing the existing and developed detention hydrographs.

h. When designing ponds in series (i.e., when the discharge of one (1) becomes the inflow of another), the engineer shall submit a hydrologic analysis which demonstrates the system's adequacy. This analysis shall incorporate the construction of hydrographs for all inflow and outflow components.

i. Areas which do not discharge into a detention pond (undetained flows) must be account for by a reduction in the allowable release rate from the detention pond equal to the discharge from the undetained area.

j. All pipes discharging into a public storm sewer system shall have a minimum diameter of 12 inches and shall be constructed of reinforced concrete. An exception can be made for discharge pipes from a filtration system.

Outlet Structure Design

There are two basic types of outlet control structures: those incorporating orifice flow and those incorporating weir flow. Weir flow is additionally broken down into two categories: rectangular and V-notch types. In each type, the bottom edge of the weir over which the water flows is called the crest. Two common types of rectangular weirs are the sharp-crested and broad-crested weirs.

Generally, if the crest thickness is more than 60% of the nappe thickness, the weir should be considered broad-crested. The coefficients for sharp-crested and broad-crested weirs vary. The design engineer shall submit weir coefficients to the City Administrative Officer for approval prior to beginning design of the weir. Weir and orifice flow equations to be used have been taken from the "Handbook of Hydraulics" by Brater and King (Ref.7) and are as follows:

a. Rectangular Weir Flow Equation (Figure 1)

$$Q = CLH^{3/2} \qquad \text{(Eq. 2A.5-1)}$$

where

Q = Weir flow, cubic feet per second
C = Weir Coefficient
L = Horizontal Length, feet
H = Depth of Flow, feet

b. V-notch Weir Flow Equation (Figure 1)

$$Q = C_v \tan (0/2) H^{2.5} \qquad \text{(Eq. 2A.5-2)}$$

where

Q = Weir Flow, cubic feet per second
C_v = Weir Coefficient
0 = Angle of the Notch at the Apex (degrees)

c. Orifice Flow Equation (Figure 1)

$$Q = C_o A_o (2gH)^{0.5} \qquad \text{(Eq. 2A.5-3)}$$

where

Q = Orifice Flow, cubic feet per **second**
C_Q = Orifice Coefficient (use 0.6)
A_Q = Orifice Area, square feet
g = Gravitational Constant, 32.2 ft/sec^2
H = Head on Orifice measured from centerline, feet

Detention Pond Storage Determination

There are several methods available for determining the runoff storage volume required for a detention pond. The design engineer shall review the design method to be used with the City Administrative Officer prior to beginning the design of the detention facility. An accepted method to be used for small drainage areas (less than 25 acres) is the modified Rational Method (MRM). For drainage areas 25 acres and greater, a hydrograph method shall be used.

a. Modified Rational Method (MRM)

The MRM was derived from the Rational Method. This methodology determines the duration which produces the total volume of runoff above the existing peak. The MRM design procedure shall be limited to sites with contributing areas less than **25** acres.

The MRM is based on the same assumptions **as** the Rational Method. The most significant assumption is that the period of rainfall averaging is equal to the duration of the storm. This means that the rain and the corresponding runoff that occurs before and after the rainfall averaging period are not accounted for. Experience in comparing detention facility volumes obtained with the Modified Rational Method to those obtained with other methods, suggest that significant underestimates of required storage volumes may result for drainage areas larger than 25 acres.

The method also assumes that an urban runoff hydrograph can be approximated as having either a triangular or trapezoidal shape. This assumption is equivalent to assuming that the contributing drainage area increases approximately linearly with time; that is, there is a linear area-time relationship for the drainage area.

The MRM is a graphical procedure to estimate the detention storage volume. The Modified Rational Method graphical procedure is only applicable for detention storage volume estimation for a single-storm event and shall not be used when a storage routing procedure is required.

b. MRM - Graphical Procedure

The following is a procedure for applying the graphical method presented by Franklin C. Houston, P.E., at the International Symposium on Hydrology, Hydraulics and Sedimentation at the University of Kentucky (Ref.9). This method is limited to a drainage area of less than 25 acres

Step 1. Use the 100 year return frequency storm for determining the maximum runoff.

Step 2. Determine the maximum allowable release rate (Q_A) (peak flow for pre-condition (R-l) Single-Family) for the site and plot as a horizontal line as shown in Figure 2.

$Q_A = C_A I A$ (Eq. 2A.5-4)

Q_A= Maximum Allowable Release Rate
C_A= Runoff Coefficient for (R-l Development) (use 0.5)
1= Rainfall Intensity (in/hr)
A= Drainage Area (acres)

Step 3. Determine the hydrologic data for the proposed postcondition drainage area. This includes the contributing area, runoff coefficient and time of concentration in the developed condition.

Step 4. Utilizing the developed post-condition time of concentration determined in Step 3, draw a corresponding vertical line as shown in Figure 2.

Step 5. Select storm durations and calculate the peak flow (Q_P) for post-conditions based on multiples of the developed post-condition time of concentration. When a duration results in a Q_P value less than Q_A this step is complete.

Q_P is expressed as a function of the storm duration. The equations for the Rational Method and rainfall intensity to be used are as follows:

$Q_P = C_P\ i_D\ A_P$ (Eq. 2A.5-5)

where

Q_P = Peak Flow Rate for proposed post-conditions, cubic feet per second

C_p = Runoff Coefficient for proposed developed post-conditions

A_p = Contributing Drainage Area for proposed developed post-conditions, acres

and

$$i_D = \frac{b}{(t_D + d)^e} = \text{Rainfall Intensity (in/hr)} \qquad \text{(Eq. 2A.5-6)}$$

where

t_D = Specific storm duration in minutes. The b, d and e coefficients in Table 1 below are taken from Table 6 in the Texas State Department of Highways and Public Transportation, Bridge Division, Hydraulic Manual (Ref. 8).

Table 2A-1
Coefficients for Equation

Storm Frequency	e	b	d
5-year	0.772	61	8.1
10-year	0.770	72	8.1
25 year	0.785	89	8.1
50 year	0.772	96	8.1
100-year	0.765	103	7.7

Step 6. As shown in Figure 2, Construct hydrographs based on the proposed post-condition peak flows and on the storm durations selected in Step 5 as illustrated in Figure 2.

Step 7. Connect a line from the origin to the intersection point of the allowable release rate line and the recession limb of the hydrograph for each duration. The required storage is represented by the difference between the triangular outflow hydrograph, which is below the release rate line and the total trapezoidal inflow hydrograph. This is depicted as the cross-hatched area in Figure 2.

Step 8. The engineer should proceed to the detention pond design.

The volume of storage required for the detention ponds as depicted in Figure 2, can be arithmetically calculated as follows:

The volume under trapezoidal inflow hydrograph is

$$V_I = 60\ (I/2)\ (Q_p)\ [t_D - t_C) + (t_D + t_C)] \quad \text{(Ref. 9)} \qquad \text{(Eq. 2A.5-7)}$$

where

t_C = Time of Concentration, minutes

t_O = Time of Duration, minutes

Q_P= Peak Flow, proposed post-conditions, cubic feet per second

and the volume under the triangular outflow hydrograph is

$$V_O = 60\ (I/2)\ (Q_A)\ (T_D + T_C) \qquad \text{(Ref. 9)} \qquad \text{(Eq. 2A.5-8)}$$

where

Q_A = Maximum Allowable Release Rate, peak flow pre-condition, cubic feet per second

The volume of storage required by the detention pond is the difference of the above two volumes.

V_R = Volume of Storage required

$$V_R = (Q_P)\ [t_D - t) + (t_D + t_C)\ ] - 60\ (I/2)\ (Q_A)\ (t_D + t_C)$$

$$V_R = 60\ (Q_P)\ (t_D) - (30\ (Q_A)\ (t_D + t_C)\ ) \qquad \text{(Eq. 2A. 5-9)}$$

A situation may occur where stormwater runoff does not flow through the detention pond, yet must be addressed in the design. This situation of "by-pass" requires the maximum allowable release rate be reduced by the peak flows generated from areas that by-pass the pond. These peak flows are calculated from the Rational Method, using the time of concentration for the given area and the corresponding rainfall intensity for the specific return period of the storm. The MRM procedures shall not be used for situations involving multiple-ponds where the outflow from one pond flows to another pond.

c. MRM - Example:

The following example will illustrate the application of the Graphical and Equation procedures in the solution of a small detention pond storage calculations using the Modified Rational Method.

GIVEN: A drainage area has the following characteristics for the pre-condition and post-condition.

Pre-Condition:
(R-l) Single-Family
Drainage Area = 3 acres
Composite runoff coefficient C = 0.5
Time of concentration (t_C) = 5 minutes

Post-Condition:
Drainage Area = 3 acres
Composite runoff coefficient C = 0.85
Time of concentration (t_C) = 5 minutes

REQUIRED: A detention pond is needed to control the excess storm runoff. Find the detention storage volume required.

SOLUTION:

Step 1. Detention ponds are to be sized based on a 100-year return frequency storm.

Step 2. The peak flow from pre-conditions (R-l) Single-Family can be calculated by the Rational Method (Eq. 2A.5-4). The rainfall intensity for a 100-year storm with a 5 minute time of concentration is 14.74 inches per hour (see Eq. 2A.5-6) and Table 2A-1).

$Q_P = CIA$
$Q_P = 0.50 \times 14.74 \times 3$
$Q_P = 22$ cfs

This peak flow of 22 cubic feet per second is used as the maximum allowable release rate for the post-condition. A horizontal line representing this release rate is plotted and illustrated in Figure 3.

Step 3. A vertical dashed line corresponding to the developed time of concentration of 5 minutes is then drawn as illustrated in Figure 3.

Step 4. Based on multiples of the developed time of concentration, construct the inflow hydrographs for storm durations of 5, 10, 15, 20 and 25 minutes. **The** corresponding rainfall intensities and peak flows calculated from the Rational Method are shown in the following table.

Table 2A-2

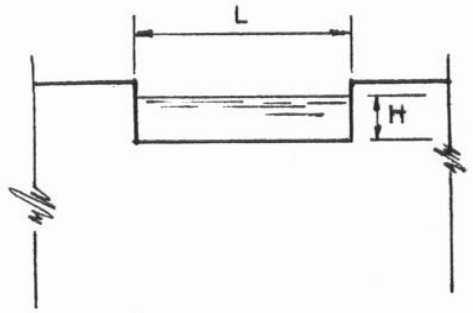
Rainfall Duration (Minutes)	Intensity (in/hr)	Peak Flow (cfs)
5	14.74	37.6
10	11.43	29.1
15	9.45 8.12	24.1
20	7.15	20.7
25		18.2

Step 5. Draw a line connecting the origin and intersection point of the allowable release rate line and the recession limb of each inflow hydrograph. Determine the corresponding storage volumes for each duration using Eq. 2A.5-9. Note that the calculation of volume for the duration of 25 minutes was not necessary since the storage curve had already exhibited a descent at 20 minutes. In addition, the 20 minute and 25 minute storm duration are not shown on Figure 3 as they both would be below the maximum allowable release rate.

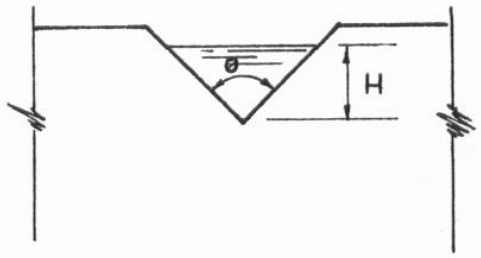
Table 2A-3

Rainfall Duration Minutes	Storage Cu. Ft.
5	4643
10	7538
15	8422
20	8264
25	7450

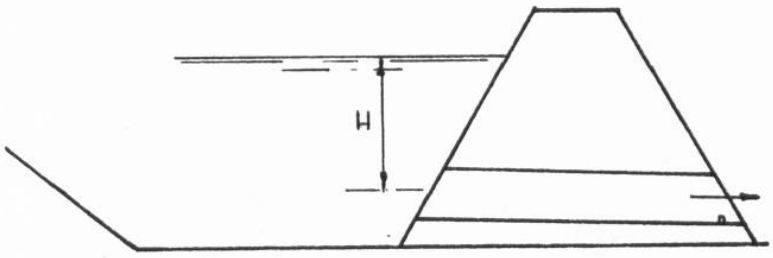
Step 6. The storage volume required is 8422 cubic feet for the detention pond.



RECTANGULAR WIER



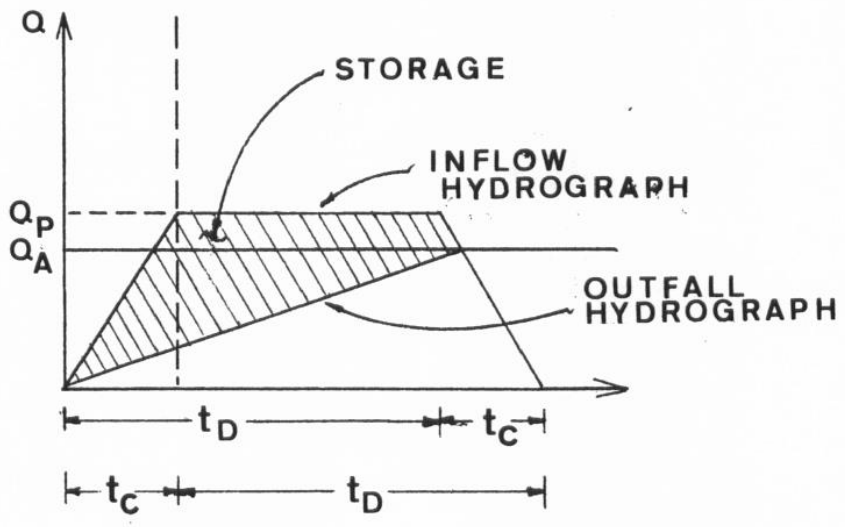
V-NOTCH WIER



ORIFICE DESIGN

WIER AND ORIFICE FLOWS

FIGURE 1



t_C :time of concentration (minutes)

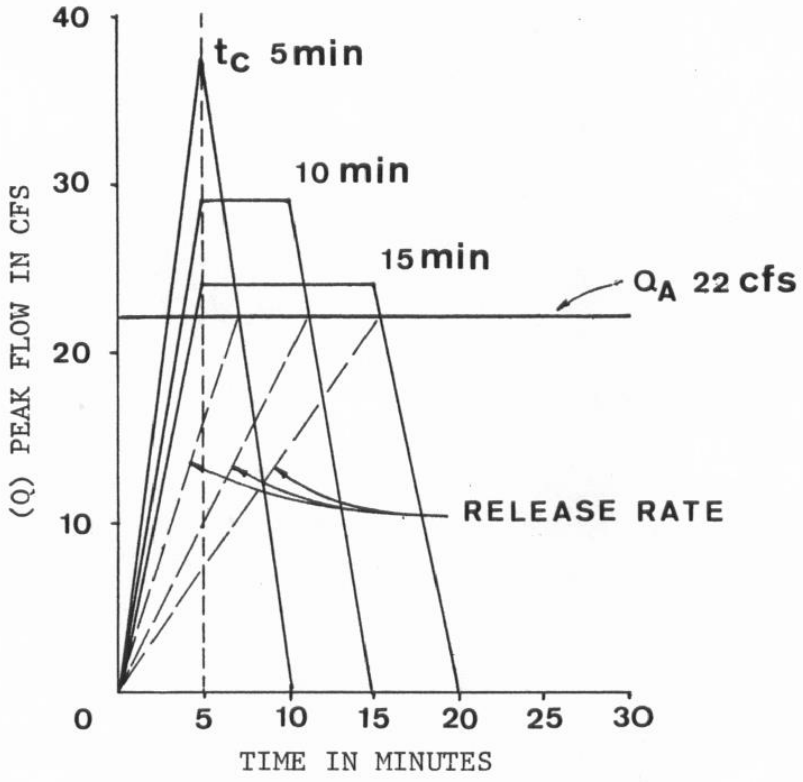
t_D :time of duration (minutes)

Q_P :peak flows (cfs)

Q_A :maximum allowable release rate (cfs)

MODIFIED RATIONAL METHOD — SCHEME

FIGURE 2



EXAMPLE OF MODIFIED RATIONAL METHOD HYDROGRAPH

FIGURE 3